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In re the application of: Kenshin Kitoh

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For: LITHIUM SECONDARY BATTERY

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Janet M. Stevens

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TRANSMITTAL OF SWORN TRANSLATION

Sir:

Pursuant to the provisions of MPEP §201.15, applicants hereby submit a sworn translation of Japanese Patent Application No. 10-153256, filed June 2, 1998. A certified copy of this document was filed on June 1, 1999 in the above-identified application. The sworn translation is being filed at this time in order to overcome the effective date of a reference applied by the USPTO in rejecting claims in the above-identified application.

Respectfully submitted,

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VERIFICATION OF TRANSLATION

I, Koji KIKAWA, a Japanese Patent Attorney, residing at 15-7, Sugano-2-chome, Ichikawa-shi, Japan, state that I am fluent in English language and Japanese language.

I hereby verify that the attached English translation of Japanese Patent Application No. H10-153256 filed with Japanese Patent Office on June 2, 1998 is a true and correct translation to the best my knowledge and belief.

Signed this 9th day of July, 2002.

By ____________________

Koji KIKAWA

PATENT OFFICE

JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

Date of Application: June 2, 1998

Application Number: H10-153256

Applicant(s): NGK Insulators, Ltd.

Commissioner,

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[ADDRESSEE]	Hisamitsu Arai Commissioner of the Patent Office
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[TITLE OF THE INVENTION]	Lithium Secondary Battery
[NUMBER OF CLAIMS]	13
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[Name of document] Specification : 1

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[Name of Document] SPECIFICATION

[Title of the Invention] Lithium Secondary Battery

[Scope of the Claim for Patent]

[Claim 1] A lithium secondary battery, comprising:

an internal electrode body including a positive electrode and a negative electrode being wound or laminated via a separator so that the positive electrode and the negative electrode are not brought into direct contact with each other, and

an organic electrolyte;

wherein at least a plurality of tabs to be connected to each of the positive and negative electrodes for current collecting have a total cross-sectional area of the tabs be not less than a constant area in accordance with the quality of the material to be used for the tabs so that each of the tabs for current collecting may not fuse when at least 100A current flows through the lithium secondary battery.

[Claim 2] The lithium secondary battery according to claim 1, wherein the relationship between the quality of the material of tabs and total cross-sectional area of the tabs is not less than 0.009 cm^2 for aluminum, not less than 0.005 cm^2 for copper, and not less than 0.004 cm^2 for nickel, and more preferably not less than 0.014 cm^2 for aluminum, not less than 0.008 cm^2 for copper, and not less than 0.008 cm^2 for nickel.

[Claim 3] The lithium secondary battery according to claim 1 or 2, wherein a thickness of the tab is not more than twice a

thickness of an electrode active material layer in an electrode to which the tabs are welded, and more preferably not more than a thickness of the electrode active material layer.

[Claim 4]

The lithium secondary battery according to any one of claims 1 through 3, wherein a sum of resistance value of the tabs per a unit battery is not more than 1 mΩ.

[Claim 5]

A lithium secondary battery, comprising:

an internal electrode body including a positive electrode and a negative electrode being wound or laminated via a separator so that the positive electrode and the negative electrode are not brought into direct contact with each other;

an organic electrolyte; and

at least a plurality of tabs to be connected to each of the positive and negative electrodes for current collecting,

wherein the tabs function as current fuses.

[Claim 6]

The lithium secondary battery according to claim 5, wherein the relationship between the quality of the tabs and total cross-sectional area of the tabs is not more than $0.36/R(cm^2)$ for copper, and not more than $0.14/R(cm^2)$ for nickel, and more preferably not more than $0.18/R(cm^2)$ for aluminum, not more than $0.99/R(cm^2)$ for copper, and not more than $0.07/R(cm^2)$ for nickel, when internal resistance of a unit battery is given as R (mΩ).

[Claim 7]

The lithium secondary battery according to claim 6, wherein the tabs are provided with a narrow portion.

[Claim 8]

The lithium secondary battery according to any one of claims 1 through 7, wherein internal resistance is not more than 10 mΩ per a unit battery.

[Claim 9]

The lithium secondary battery according to any one of claims 1 through 8, wherein the relationship between the quality of the material of the tabs and total cross-sectional area of the tabs is not less than 0.008 cm^2 and not more than 0.36/R cm^2 for aluminum, not less than 0.005 cm^2 and not more than 0.18/R cm^2 for copper, and not less than 0.004 cm^2 and not more than 0.14/R cm^2 for nickel, and more preferably not less than 0.014 cm^2 and not more than 0.18/R cm^2 for aluminum, not less than 0.008 cm^2 and not more than 0.09/R cm^2 for copper, and not less than 0.008 cm^2 and not more than 0.07/R cm^2 for nickel, when internal resistance of a unit battery is given as R(mΩ).

[Claim 10]

The lithium secondary battery according to any one of claims 1 through 9, wherein deviation of respective resistance values of the tabs is within ±20% of an average value.

[Claim 11]

The lithium secondary battery according to any one of

claims 1 through 10, wherein an end part of the tab at the side with no connection taking place with the electrodes is connected by pressure attachment, welding or eyelet.

[Claim 12]

The lithium secondary battery according to any one of claims 1 through 11, wherein battery capacity is not less than 5 Ah.

[Claim 13]

The lithium secondary battery according to any one of claims 1 through 12, wherein the battery is used for an electric vehicle or a hybrid electric vehicle.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a lithium secondary battery which maintains a good charge-discharge cycle and in which safety may be secured with electricity being cut off when an excess current has occurred due to external short circuit, etc. so that the battery may not be exploded or ignited, and in particular, to a lithium secondary battery which may be preferably used for driving a motor of an electric vehicle, etc.

[0002]

[Prior Art]

In recent years, in midst that it is eagerly desired to regulate the mission of exhaust gas including carbon dioxide and

other harmful substances with the elevation of environment protection campaign as a background, the campaign to promote an introduction of an electric vehicle (EV) and a hybrid electric vehicle (HEV) has become active in replacement of automobiles using fossil fuels such as a vehicle driven by gasoline in the automobile industry. A lithium secondary battery as a motor-driving battery acting as a key for putting such EV as well as HEV into practical use, is required to have not only huge battery capacity but also a huge battery output much affecting acceleration performance as well as gradeability of a vehicle, and on the other hand, however, a strict safe standard has been established from the point of view of securing safety since the battery is provided with high energy density.

[0003]

In general, the internal electrode body of a lithium secondary battery comprises a positive electrode, a negative electrode and a separator made of porous polymer film, the positive electrode and the negative electrode being wound or laminated via the separator so that the positive electrode and negative electrode are not brought into direct contact with each other. For example, as shown in Fig. 1, an internal electrode body 1 of winding type is formed by winding a positive electrode 2 and a negative electrode 3, having a separator 4 in between, and tabs 5 are provided for each of positive and negative electrodes 2, 3 (hereafter referred to "electrodes 2, 3") respectively. And, the

ends opposite to the ends connected with electrodes 2, 3 of each tab 5 are attached to an external terminal (not shown) or an electric current extracting terminal (not shown) being conductive to the external terminal. That is, the tab 5 serves to act as a lead line (a current path) being conductive to the external terminal, etc. together with conducting current collecting from electrodes 2, 3.

[0004]

Here, Fig. 2 shows a plan view of the electrodes 2, 3 when the internal electrode body 1 is spread out. The electrodes 2, 3 are formed with an electrode active material being coated respectively onto metal foils 15 made of aluminum, etc. for positive electrode 2 and made of copper for negative electrode 3 respectively as current collecting bodies, thus forming an electrode active material layer 16.

[0005]

The tab 5 is provide on one side of such a metal foil 15, and those having thin band shape are preferably used so that the position where the tab 5 of the electrodes 2, 3 are attached may not swell to the direction of a periphery when the internal electrode body 1 was formed. In addition, they are preferably disposed in approximately uniform distance so that one tab 5 conducts current collecting from a constant area in the electrodes 2, 3. Incidentally, in general, a material to be used for the tab 5 is the same as a material of the metal foil 15 to which the tab 5 is

attached.

[0006]

[Problems to be Solved by the Invention]

Incidentally, in an EV or HEV, it is necessary to use a plurality of single batteries connected in series in the case of lithium secondary batteries with a voltage of around 4V at the highest for a single battery since a constant voltage is required to drive a motor, and, however, there is a case where discharge of a large current not less than 100A is required to obtain the herein desired acceleration performance or gradeability. For example, assuming that 200V with 100A be required and 3.6V be an average terminal voltage at the time of discharge thereof, 56 units of single batteries are required to be connected in series, resulting 100A current flowing at each single battery at this time.

[0007]

The internal structure of a battery must be designed so that also in the case where such a huge current flows, the battery may normally operate while the output loss is suppressed as low as possible. Therefore, paying attention to the current path from the above described internal electrode body 1 and the external terminal, it is deemed preferable that the resistance of members themselves of the electrodes 2, 3 as well as the metal foils 15, or the tabs 5 and the external terminals, etc., all configuring the electrodes 2, 3 is small.

[0008]

However, from the point of view of securing battery capacity as well as securing mechanical strength of electrodes, few degrees of freedom in setting quantity of the electrode active material layer 16 configuring the electrodes 2, 3 and sizes of the metal foils 15 are permitted; while as concerns the electric current extracting terminal 13, normally considering the shape of batteries, or the energy density thereof, the quantity of the maximum discharge current, light-weight low-resistance members with resistance values of not more than a predetermined value within a range which is possible to set are used.

[0009]

On the other hand, the tab 5 has an allowable range to set up a resistance value on a point of feasibility to set up its shape freely as far as the shape of the tab 5 is housed in the space between the battery case housing the internal electrode body 1 therein and the internal electrode body 1. Metal members are used for the tab 5, whose resistance value is generally made smaller, nevertheless, the rate of the resistance value of the tab occupying in the total internal resistance of a lithium secondary battery is not necessarily small, and cannot be ignored.

[0010]

On condition that a plurality of the above described tabs 5 in the shape of foil band are used, a tab 5 adopting a larger cross-sectional area to make the resistance value smaller will result in introducing a situation where energy density of a battery

gets decreased since the total weight of the tabs 5 becomes heavier in spite that effective decrease in the internal resistance and effective decrease in the output loss is expected.

[0011]

On the contrary, making the cross-sectional area of the tabs 5 smaller decreases the total weight of the tabs 5 and increases battery's energy density, but on the other hand there will occur such problems that the resistance value of the tabs 5 increases, the tabs 5 fuses due to increase in output loss because of increase of internal resistance or heat generated by current, and thus functions as a battery will disappear. Accordingly, from the standpoint to avoid such problems and do well both in reducing output loss and increasing energy density, cross-sectional area of not less than a certain value is required for the tabs 5.

[0012]

On the other hand, with respect to the above described problems, it is feared that an accident involving an explosion or an ignition may occur when a great current has been discharged at a time due to an external short circuit, etc., since a lithium secondary battery has higher energy density, and for the purpose of avoiding such situation in advance, "Guideline for safety evaluation on secondary lithium cells (hereafter referred to SBA Guidelines)" published by Battery Association of Japan stipulates that a lithium secondary battery should be free from burst or ignition to be evidenced by an external short circuit test. To

fulfill such a standard, in a lithium secondary battery various safety devices such as a current-limiting mechanism comprising a PTC element, a release mechanism of battery's internal pressure involving safety values, pressure joints, etc., are incorporated and proposed.

[0013]

Here, a current fuse is utilized in various electric appliances, but has never been used up to date as a current cutoff mechanism to be disposed inside a lithium secondary battery since a size or a shape of the current fuse is subject to a limit. However, if the tab 5 can function as the current fuse, with which an existing safety device may be replaced or concurrently disposed, it is deemed that a safety increase may be planned.

[0014]

In the case where the tab 5 is used as a current fuse like this, the current cutoff value must be determined so that the tab 5 is fused with a predetermined quantity of excess current, but as mentioned above, there is naturally a limit in the structural shape of the tab 5. That is, for the purpose of using the tab 5 as a current fuse, the cross-sectional area of the tab 5 must be set not more than a predetermined value, but at the same time, considering the fact that the quantity of excess current may also defer due to quantity of single battery's internal resistance, it is regarded as necessary to set the cross-sectional area of the tab 5 in accordance with quantity of a single battery's internal

resistance.

[0015]

[Means to Solve the Problem]

The present invention was attained by contemplating the problems of the prior art mentioned above, and its first object is to provide a lithium secondary battery having realized reduction in output loss and increase in energy density, and its second object is to provide a lithium secondary battery which has been planned to secure and increase in safety by incorporating tabs into the battery as a current fuse, being a replacement for a conventional safety device or to be concurrently disposed, and furthermore, its third object is to provide a lithium secondary battery which concurrently realizes these characteristics, that is, reduction in output loss and increase in energy density, and security of safety with imparting a function as a current fuse to tab.

[0016]

That is, according to the present invention, there is provided a lithium secondary battery, comprising:

an internal electrode body including a positive electrode and a negative electrode being wound or laminated via a separator so that the positive electrode and the negative electrode are not brought into direct contact with each other, and

an organic electrolyte;

wherein at least a plurality of tabs to be connected to each of the positive and negative electrodes for current collecting have

a total cross-sectional area of the tabs be not less than a constant area in accordance with the quality of the material to be used for the tabs so that each of the tabs for current collecting may not fuse when at least 100A current flows through the lithium secondary battery.

[0017]

In such a lithium secondary battery of the present invention, although the relationship between the quality of the material of tabs and total cross-sectional area of the tabs is preferably not less than 0.009 cm^2 for aluminum, not less than 0.005 cm^2 for copper, and not less than 0.004 cm^2 for nickel, and more preferably not less than 0.014 cm^2 for aluminum, not less than 0.008 cm^2 for copper, and not less than 0.008 cm^2 for nickel. A thickness of the tab is not more than twice a thickness of an electrode active material layer in an electrode to which the tabs are welded, and more preferably not more than a thickness of the electrode active material layer; that is, it is preferred that the thickness is set within a range where the portions where the tabs have been attached shall not swell when the tabs are attached to electrodes to be wound or laminated. Incidentally, from the point of view of reduction in internal resistance, a sum of resistance value of the tabs per a unit battery is preferably not more than 1 mΩ.

[0018]

According to the present invention, there is further

provided a lithium secondary battery, comprising:

an internal electrode body including a positive electrode and a negative electrode being wound or laminated via a separator so that the positive electrode and the negative electrode are not brought into direct contact with each other;

an organic electrolyte; and

at least a plurality of tabs to be connected to each of the positive and negative electrodes for current collecting,

wherein the tabs function as current fuses.

[0019]

In such a lithium secondary battery, the relationship between the quality of the tabs and total cross-sectional area of the tabs is preferably not more than 0.36/R(cm^2) for copper, and not more than 0.14/R(cm^2) for nickel, and more preferably not more than 0.18/R(cm^2) for aluminum, not more than 0.99/R(cm^2) for copper, and not more than 0.07/R(cm^2) for nickel, when internal resistance of a unit battery is given as R (mΩ). In addition, if the tabs are provided with a narrow portion, the tab is easily made to function as a current fuse, which is preferable.

[0020]

It is preferable that the internal resistance in the aforementioned lithium secondary battery of the present invention is not more than 10 mΩ per a unit battery. In addition, by setting the relationship between the quality of the material of the tabs and total cross-sectional area of the tabs not less than 0.008

cm^2 and not more than 0.36/R cm^2 for aluminum, not less than 0.005 cm^2 and not more than 0.18/R cm^2 for copper, and not less than 0.004 cm^2 and not more than 0.14/R cm^2 for nickel, and more preferably not less than 0.014 cm^2 and not more than 0.18/R cm^2 for aluminum, not less than 0.008 cm^2 and not more than 0.09/R cm^2 for copper, and not less than 0.008 cm^2 and not more than 0.07/R cm^2 for nickel, a battery having the characteristics of the above described two kinds of lithium secondary batteries can be obtained.

[0021]

Incidentally, when deviation of respective resistance values of the tabs is within $\pm 20\%$ of an average value, fusing at one tab causes increase in current flowing through the other tabs without making a large current flow into one tab with priority since difference in quantity of current related to the tabs is small, thus fusing of the tabs can be controlled not to occur in a chained fashion. It goes without saying that lack of variance in shape of respective tabs is preferred for the purpose that such deviation of resistance values of tabs is made smaller, and moreover, when an end part of tabs opposite to the end connected with electrodes is connected by pressure attachment, welding or eyelet, deviation of resistance for each tab having been connected with a battery can be reduced and preferable.

[0022]

The characteristics of the above described lithium

secondary battery of the present invention are preferably adopted as a lithium secondary battery with battery capacity of not less than 5Ah, and the lithium secondary battery of the present invention is preferably used for an electric vehicle (EV) or for a hybrid electric vehicle (HEV).

[0023]

[Mode for Carrying Out the Invention]

An internal electrode body of a lithium secondary battery of the present invention (hereinafter referred to as "battery") comprises a positive electrode, a negative electrode and a separator made of porous polymer film, the positive electrode and the negative electrode being wound or laminated for configuration so that the positive electrode and negative electrode are not brought into direct contact with each other via the separator. In particular, as earlier shown in Fig. 1, a wound-type internal electrode body 1 is formed by winding a positive electrode 2 and a negative electrode 3 via a separator 4, and tabs 5 are provided for the electrodes 2, 3. Incidentally, these tabs 5 can be attached to the electrodes 2, 3 with means such as supersonic welding, etc. at the time when the electrodes 2, 3 are wound together with the separator 4.

[0024]

On the other hand, as shown in Fig. 3, the lamination-type internal electrode body 7 laminates the positive electrode 8 and the negative electrode 9 alternatively via the separator 10 with

tabs 6 being connected to each of positive and negative electrodes 8 and 9 (hereinafter referred to "electrodes 8, 9") respectively. Such internal electrode bodies 1, 7 have a structure of basically having have a plurality of element batteries being connected in parallel, the element battery comprising positive electrodes 2, 8 and negative electrodes 3, 9 facing each other.

[0025]

The positive electrodes 2, 8 and the negative electrodes 3, 9 are all produced by forming an electrode active material layer with electrode active materials being coated respectively onto metal foils as the current collecting body. Here, aluminum foils are preferably used as the current collecting body for positive electrodes 2, 8 and copper foils as the current collecting body for negative electrodes 3, 9 respectively, but titanium foils may be used as the current collecting body for positive electrodes 2, 8 and nickel foils as the electrode collecting body for negative electrodes 3, 9.

[0026]

For a battery with any of above described configurations, lithium transition metal compound oxides such as lithium cobalt oxide ($LiCoO_2$), lithium nickel oxide ($LiNiO_2$), lithium manganese oxide ($LiMn_2O_4$), etc. are generally used as a positive active materials. Incidentally, in order to improve the conductivity of these positive active materials, it is preferable to mix with an electrode active material a carbon powder such as acetylene black,

graphite powder, etc. On the other hand, for the negative active materials, an amorphous carbon material such as soft carbon or hard carbon, or carbon powder such as artificial graphite and natural graphite, etc., is used. These electrode active materials are transformed into a slurry, coated onto the current collecting body and stuck, thus the electrodes 2, 3, 8, 9 are produced.

[0027]

As the separators 4, 10, it is preferable to use one having a three-layer structure in which a polyethylene film having lithium ion permeability and including micropores is sandwiched between porous polypropylene films having lithium ion permeability. This serves also as a safety mechanism in which when the temperature of internal electrode bodies 1, 7 are raised, the polyethylene film is softened at about 130℃ so that the micropores are collapsed to suppress the movement of lithium ions, that is, the battery reaction. And, since this polyethylene film is sandwiched between the polypropylene films having a softening temperature higher than the said polyethylene film, it becomes possible to prevent the direct contact between the electrodes (2, 3), (8, 9).

[0028]

Below, the present invention will be explained by using the case of a wound-type internal electrode body 1 as an example. Fig. 4 is a cross-sectional view showing one embodiment of the battery structure. The internal electrode body 1 has been inserted in a battery case 11 with the tab 5 of the positive

electrode 2 having been connected to a rivet 13 attached on a positive terminal plate 12, and the tab 5 of the negative electrode 3 having been connected to a rivet 13 attached on a negative terminal plate 14 respectively by pressure attachment.

[0029]

Electrolyte has been injected inside the battery case 11, and as the electrolyte a carbonic acid ester family such as ethylene carbonate (EC), diethyl carbonate (DEC), and dimethyl carbonate (DMC), and a nonaqueous organic electrolyte in which one or more kinds of lithium fluoride complex compound such as $LiPF_6$, and $LiBF_4$, etc., or lithium halide such as $LiClO_4$ as an electrolyte are dissolved in a single solvent or mixed solvent of organic solvents such as propylene carbonate (PC), γ-butyrolactone, tetrahydrofuran, and acetonitrile, etc., are preferably used. Such electrolyte can be injected by injecting it from an open end after the other end of the battery case is sealed, and thereafter, the open end is blockaded.

[0030]

Incidentally, since metal material is generally used as the battery case 11, it is preferable that an insulating sheet 17 is disposed on the internal wall of the battery case 11 so as to secure insulation for the internal electrode body 1 and the battery case 11. But the function of this insulating sheet 17 may be replaced by the separator 4.

[0031]

In addition, in a battery shown in Fig. 4, when metal material is used for the positive terminal plate 12 as well as the negative terminal plate 14, it is necessary to provide insulation between the battery case 11 and the positive terminal plate 12 as well as the negative terminal plate 14, and thus for the purpose of completing the battery seal, sealing member 20 has been used. Moreover, outside the positive terminal plate 12 as well as the negative terminal plate 13, external terminals 18 have been respectively provided and V-shape grooves 19 have been formed so that the V-shape grooves 19 function as safety valves (pressure release valves) when the battery's internal pressure increases.

[0032]

Within the range of normal working current of such a battery, the tabs 5 must carry out its function as a current path without fusing. As for batteries for EV and HEV, it does not rarely occur that a huge current such as 100A flows as a normally required current. Accordingly, in the present invention, the total cross-sectional area of the tabs 5 is supposed to have not less than a constant area in accordance with quality of the material to be used for the tab 5 so that at least a plurality of tabs 5 for current collecting to be connected to the electrodes 2, 3 should not respectively fuse also when such a huge current has flown. The predetermined area differs, depending upon the difference in melting point and resistivity due to the quality of material.

[0033]

Specifically, in a unit battery the relationship between material of the tab and total cross-sectional area of the tab is preferably not less than 0.009 cm^2 for aluminum, not less than 0.005 cm^2 for copper, and not less than 0.004 cm^2 for nickel as explained in detail in later described examples. If such cross-sectional area is secured, an incident that the tab 5 fuses and brings function of the battery to a halt even when a current of 100A flows can be avoided regardless of the resistance value of the internal electrode body.

[0034]

On the other hand, when the current value is huge, a voltage drop depending on the battery's internal resistance (hereafter referred to "internal resistance") becomes greater, but in such a case the voltage of closed circuit might go down under 3V, which may frequently cause a problem in practical use. Therefore, it is necessary to suppress the internal resistance not more than 10 mΩ, and for that purpose it is preferable to limit the resistance value of entire tabs 5 to not more than 1 mΩ per a unit battery. From such point of view, it is preferable to make total cross-sectional area of the tabs 5 not less than 0.014 cm^2 for aluminum, not less than 0.008 cm^2 for copper, and not less than 0.008 cm^2 for nickel.

[0035]

In addition, it is preferable that thickness of a tab 5 is not more than twice the thickness of an electrode active material

layer 16 in the electrodes 2, 3 to which the tab 5 is welded and further preferably is not more than the thickness of the electrode active material layer 16. Here, with reference to Fig. 2 the thickness of the electrode active material layer 16 refers to the thickness of the electrode active material layer 16 of a unit layer formed on either side of the metal foil 15, that is one-side coating thickness.

[0036]

Figs. 5(a) and 5(b) are enlarged cross-sectional views showing one embodiment of the attachment part of the tabs 5 into the electrodes 2, 3 at the positive side in Fig. 4. But, it goes without saying that the similar idea can also be applied to arrangements for the negative side. As shown in Fig. 5(a), if thickness of the tab 5 is not more than twice the thickness of an electrode active material layer 16 in the positive electrode 2 to which the tab 5 is attached, the metal foil 15 and the separator 4 are bent in use of the space provided in the end part where any electrode active material layer 16 has not formed, thus the risk that the tabs 5 contacts the positive electrode plate 2 gets smaller. In addition, since such status where the part to which the tab 5 is attached swells toward the periphery and the external diameter of the internal electrode body 1 partially expands can be avoided, inconvenience hardly occurs for housing of the internal electrode body into the battery case 11. Moreover, as shown in Fig. 5(b), when thickness of a tab 5 is not more than the thickness of the

electrode active material layer 16, neither short circuit to the above described opposite pole nor swelling at the attachment part of the tabs 5 will occur and thus will be more preferable.

[0037]

Incidentally, if the total cross-sectional area of the tabs 5 gets greater with the length of tabs 5 being constant, the percentage of weight of tabs 5 occupying the battery increases, which becomes, thus, disadvantageous from the viewpoint of energy density. Accordingly, it is preferable that the cross-sectional area of the tabs 5 is determined within the range where the tabs do not fuse for the above described predetermined current values, and moreover by considering thickness as well as weight of the tabs 5.

[0038]

Now, in a battery shown in Fig. 4, safety valves using V-shape grooves 19 are only provided in each of positive and negative terminal plates 12, 14 as safety mechanism against excess current such as short circuit current, but, otherwise, it goes without saying that safety mechanisms may be concurrently provided, that is, a PTC element may be provided, or a pressure joint may be provided between the rivet 13 and the external terminal 18. However, the time when these safety mechanisms operate only comes after a huge current has already flown. Under the circumstances, it may be thought that current fuse is disposed in a circuit outside a battery as a mechanism to cut off a

current instantly at approximately the same time of occurrence of a huge current.

[0039]

However, the SBA guidelines stipulates that a lithium secondary battery should be free of burst or ignition to be evidenced by an external short circuit test. Under the circumstances, improvement in safety seems to be able to be planned if a current fuse may be incorporated in a battery, that is, the tabs 5 which are connected to the internal electrode body may be used also as a current fuse when abnormality in the internal electrode body being the source of current has occurred.

[0040]

Based on such theory, in the present invention, at least a plurality of tabs 5 for current collecting to be connected to the electrodes 2, 3 are made to function as current fuses, but in this case, the internal resistance much affects a current value due to which the current fuse works. That is, even if an internal short circuit or an external short circuit takes place, when the internal resistance is huge, a short circuit current does not get larger while much larger excess current flows when the internal resistance is small. Therefore, the fusing current value of a current fuse is preferably set in accordance with the internal resistance. Here, although shapes of tabs 5 may be the same, difference in material results in showing different melting point and resistance value, thus, this current cutoff value is preferably

set in accordance with the material of the tabs 5, and may be determinable by total cross-sectional area of tabs 5.

[0041]

That is, as concerns a current fuse, in the present invention, the relationship between material of the tabs 5 and total cross-sectional area of the tabs is preferably not more than 0.36/R (cm^2) for aluminum, not more than 0.18/R (cm^2) for copper, and not more than 0.14/R (cm^2) for nickel as explained in detail in the later described examples, when internal resistance of a unit battery is given as R (mΩ). In addition, for the purpose of making tabs 5 functional as current fuses even if the external short circuit resistance is around one time the internal resistance, it is preferable to set not more than 0.18/R (cm^2) for aluminum, not more than 0.09/R (cm^2) for copper, and not more than 0.07/R (cm^2) for nickel. By setting the resistance value of tabs 5 within such a range, a current may be cut off without making a safety valve operate, namely without driving out vaporized gas of such as an electrolyte, etc. from inside a battery.

[0042]

Incidentally, as shown in Fig. 6, narrow parts 21 may be preferably provided in the tabs 5, making it easier for the tabs 5 to function as current fuses. In this case, total cross-sectional area of tabs 5 refers to total cross-sectional area of parts where the cross-sectional area of the narrow parts 21 becomes the smallest.

[0043]

Also in such a battery where the tabs 5 are provided with function as a current fuse, the internal resistance is preferably not more than 10 mΩ per a unit battery. This is due to a request from a practical point of view that a voltage drop at the time of normal use should be preferably made as small as possible and the output loss should be preferably made as small as possible.

[0044]

For the purpose of obtaining a battery having the two kinds of battery characteristics according to the above described present invention, namely tabs 5 never fusing because of a huge current under normal working conditions of a battery, and on the other hand the tabs 5 having a function to fuse as current fuses when an excess current such as a short circuit current, etc. has flown, it will do if the relationship between material of the tabs 5 and total cross-sectional area is set at not less than 0.008 cm^2 and not more than 0.36/R cm^2 for aluminum, not less than 0.005 cm^2 and not more than 0.18/R cm^2 for copper, and not less than 0.004 cm^2 and not more than 0.14/R cm^2 for nickel, and further preferably at not less than 0.014 cm^2 and not more than 0.36/R cm^2 for aluminum, not less than 0.008 cm^2 and not more than 0.18/R cm^2 for copper, and not less than 0.008 cm^2 and not more than 0.14/R cm^2 for nickel.

[0045]

Incidentally, without taking the present invention in

particular, in a unit battery, when each tab 5 differs in terms of resistance value, there will occur difference in the value of current flowing through each tab 5, and a huge current will first flow in a tab 5 with small resistance value, resulting in fusing of the tab 5, thus, the current paths reduce to concentrate currents into the remaining tabs 5, and finally fusing of tabs 5 will occur in a chained fashion. For the purpose of avoiding such chain-fusing of tabs 5, it is preferable that variation of respective resistance values of the tabs 5 is arranged to remain within ±20% of an average value.

[0046]

For example, it goes without saying that no variance in shape of respective tabs 5 is preferred so that such deviation of resistance values of tabs 5 is made smaller, and moreover, when an end part opposite to the end connected with electrodes of the tabs 5 is connected by pressure attachment or welding or eyelet, deviation of resistance of the tabs 5 in a unit battery can be reduced and preferable. In such a connection method, it is thought that an alumina film formed on a surface of a tab made of aluminum (hereinafter referred to "Al tab"), and a copper oxide film formed on a tab made of copper (hereinafter referred to "Cu tab") will respectively be destroyed to reduce contact resistance between tabs 5, and connection by metal parts genuinely of tabs 5 may become feasible, thus deviation in resistance value may be controlled.

[0047]

The characteristics of the above described lithium secondary battery of the present invention are preferably adopted as a lithium secondary battery with battery capacity of not less than 5 Ah, and the lithium secondary battery is preferably used for an electric vehicle (EV) or for a hybrid electric vehicle (HEV).

So far, a case involving a wound-type internal electrode body 1 has been explained as an example of embodiment of the present invention, however, it is obvious that the above described conditions are applicable to the case involving a lamination type internal electrode body 7 as well.

Next, the present invention is explained in further detail by way of examples, but it goes without saying that the present invention is not limited to the above described embodiments as well as following examples.

[0048]

[Example] (Measurement of resistance value and current-proof value of a tab)

For the purpose of checking out materials of a tab, cross-sectional area thereof, and a current value with which the tab does not fuse, whether fusing occurs or not was checked out, involving tabs respectively made of various kinds of materials whose width is 10 mm, length is 50 mm and thickness is different from each other, with both ends being grasped and a predetermined current being made flow by way of a

constant-current power supply for two minutes. Test conditions and results are indicated in Table 1.

[0049]

[Table 1]

Test sample number	Quality of material	Thickness (μm)	Current value (A)	Presence of fusing of a tab
1	Aluminum	20	25	None
2		20	30	Present
3		50	50	None
4		50	60	None
5		50	70	Present
6	Copper	10	25	None
7		10	30	Present
8		20	40	None
9		20	50	Present
10		30	50	None
11		30	60	None
12		30	70	Present

[0050]

It is understood that as a result shown in Table 1, in the case where tabs are made of aluminum, four sheets each with 20 μm thickness (total cross-sectional area: 0.008 cm^2) and approximately 1.7 sheets each with 50 μm thickness (total cross-sectional area: 0.0085 cm^2) are to be required so that the tabs do not fuse at 100 A. Accordingly, in the case of an Al tab, if it has total cross-sectional area of not less than 0.009 cm^2, it shall not fuse at a 100 A current.

[0051]

Likewise, it is understood that in the case where tabs are made of copper, four sheets each with 10 μm thickness (total

cross-sectional area: 0.004 cm^2) and approximately 1.7 sheets each with 30 μm thickness (total cross-sectional area: 0.005 cm^2) is to be required. Accordingly, in case of a Cu tab, if it has total cross-sectional area of not less than 0.005 cm^2, it shall not fuse at a 100 A current. Incidentally, also for tabs made of nickel (hereinafter referred to "Ni tab") experiments similar to those described above was conducted to find out that total cross-sectional area free from fusing at 100 A current was not less than 0.004 cm^2.

[0052]

On the other hand, resistance values of one sheet of tab have been measured, average values of which was 7mΩ for an Al tab (cross-sectional area: 0.002 cm^2) with thickness of 20 μm, 8 mΩ for a Cu tab (cross-sectional area: 0.001 cm^2) with thickness of 10 μm, and 8 mΩ for an Ni tab (cross-sectional area: 0.001 cm^2) with thickness of 10 μm. Therefore, from the view point of reduction in the internal resistance, for the purpose of controlling resistance values of the tabs to not more than 1 mΩ, seven sheets of Al tab with thickness of 20 μm, that is, not less than 0.014 cm^2 in terms of total cross-sectional area, and eight sheets of Cu tab or Ni tab with thickness of 10 μm, that is, not less than 0.008 cm^2 in terms of total cross-sectional area will do. In the case where tabs with a variety of thickness are used without changing materials, it will work well if a certain number of tabs to be used are set in accordance with thickness so that such predetermined total

cross-sectional areas may be provided.

[0053]

Incidentally, in batteries for EV or HEV, it is assumed a current with a value close to 200 A should flow, but it is to be understood that approximately 200 A current may be tolerable with such a total cross-sectional area that provides with tab's resistance not more than 1 mΩ since the total cross-sectional area is approximately twice the total cross-sectional area which does not fuse at the formerly-described 100 A.

[0054]

(Forming of a battery and current-carrying test)

Next, batteries having a structure shown in Fig. 4 for examples and comparative examples were produced according to the following method. At first, a paste was prepared with $LiMn_2O_4$ powder as a positive active material, to which acetylene black was added to give conductivity to this, and further a binder and a solvent were mixed therewith. With this paste being coated on the both sides of an aluminum foil with thickness of 25 μm, a positive electrode 2 was produced having an electrode plane shape of the length towards winding direction 3600 mm × the width 200 mm. On the other hand, a paste was produced with a highly graphitized carbon powder as a negative active material, with which a binder and a solvent were mixed, and the paste was coated on the both sides of a copper foil with thickness of 20 μm, and thereby a negative electrode 3 was produced having a

electrode plane shape of the length towards winding direction 4000 mm × the width 200 mm.

[0055]

Subsequently, the thus-formed positive electrode 2 and negative electrode 3 were wound with insulation by 220 mm-wide separators 4 made of polypropylene and at the same time the number of sheets indicated in Table 2 of each of an Al tab with 10 mm width, 50 mm length, and 20 μm thickness and a Cu tab with 10 mm width, 50 mm length, and 10 μm thickness were attached respectively to the electrodes 2, 3 by ultrasonic-welding so that they were arranged to make an approximate straight line along the direction of diameter of the internal electrode body 1, and so that each of electrodes 2, 3 was placed at even distance when they were spread out, and further so that one of the electrodes was formed at one end of the internal electrode body 1.

[0056]

[Table 2]

	Number of Al tabs	Number of Cu tabs	Method of connection with a current extracting terminal	Result of 100 A current flow	Result of 200 A current flow
Example	10	10	Pressure attachment by rivet	Fusing did not occur	Fusing did not occur
Comparative example 1	2	2	Pressure attachment by rivet	Fusing occurred	Test not feasible
Comparative example 2	10	10	Tightening by screw	Fusing did not occur	Fusing occurred

[0057]

Next, as for batteries related to Example and Comparative example 1, the thus-produced internal electrode body 1 was fitted in to the aluminum-made battery case 11, with tabs 5 being arranged respectively to each positive electrode and negative electrode as shown in Fig. 7 and pressure-attached to rivets 13 which served as the current extracting terminals under pressure of 1 ton/cm^2, attaching a copper-made negative terminal plate 14 onto the negative rivet 13 and an aluminum-made positive terminal plate 12 onto the positive rivet 13 respectively. And then the negative side of the battery case 11 was sealed, and thereafter, from the open side of positive terminal of the battery case 11, the electrolyte, a mixed solvent of EC and DEC where electrolyte $LiPF_6$ was dissolved to yield 1 mol% density, was injected into the case and thereafter, the positive side was sealed tightly.

[0058]

On the other hand, as for batteries related to Comparative example 2, as shown in Fig. 8, using an current extracting terminal comprising a bolt 24 and a nut 25, tabs 5 were sandwiched between that bolt 24 and the nut 25 to be fixed. The other conditions were set to be the same as those for a battery related to Example. Initial capacity of any of thus-formed batteries related to Example and Comparative examples was 25 Ah.

[0059]

Incidentally, on the occasion of producing batteries for Example and Comparative examples 1, 2, deviation of resistance (resistance distribution) of tabs 5 to be caused by difference in the method of connection between tabs 5 and current extracting members was examined in advance by measuring voltage at the time when 1 A current flew an external terminal 18 conducting to each tab 5 and to a rivet 13 as shown in Fig. 9 for the cases of Example and Comparative example 1. In addition, also for the case of Comparative example 2, between tabs 5 and the bolt 24, deviation of resistance of tabs 5 were measured by a similar method. The results revealed that in Example as well as in Comparative example 1, deviation of resistance of tabs 5 ranged within ±20% of an average value while in the case of Comparative example 2, a wider deviation which was not plotted within the

range of ±20% of an average value was presented.

[0060]

Successively, an operation test on a battery was conducted by discharging currents of 100 A and 200 A into the formed battery. Results are also put down in Table 2. In the battery of Example, fusing of tabs 5 was not observed, but normal operation was conducted under a current value of any of 100 A and 200 A. However, in the battery of Comparative example 1, fusing of tabs 5 was observed, and normal operation of the battery was not conducted even at discharge of 100 A. On the other hand, in a battery of Comparative example 2, no problem occurred at discharge of 100 A, but the tabs fused at discharge of 200 A.

[0061]

As concerns a battery for Comparative example 2, the tabs 5 have the same total cross-sectional area as that in Example, but there is a difference in method of connection between tabs 5 and an current extracting terminal. As for aluminum foils and copper foils, oxidated film is apt to be formed on their surfaces, and therefore, it is presumed that current concentration took place at a certain tab 5 to fuse as a result of deviation of resistance values of each tab 5 occurring due to differences in the connection state of tabs 5, affected by oxidated film because of lower pressure of pressure attachment in Comparative example 2 as compared with the case of Example, and moreover reduction of current paths due to that fusing resulted in occurrence of fusing of tabs 5 in a chain

fashion. Consequently, it is understood that preferably deviation of respective resistance values of tabs 5 ranges within ±20% of the average value.

[0062]

(External short circuit test)

Next, batteries having the same structure as the one in the above described Example with cross-sectional area of tabs 5 having been made sufficiently wider were produced, and an external short circuit test was conducted. At this time, the resistance value of the external short circuit (hereinafter referred to "external circuit resistance") was made to change corresponding to internal resistance. Consequently, in the case where an external circuit resistance was set 1.5 times the internal resistance, the safety valve did not operate similar to the case of normal discharge after short circuit. In addition, in the case where external circuit resistance was set 1 time the internal resistance, the safety valve operated after short circuit but no burst nor ignition of batteries were observed. On the contrary, in the case where external circuit resistance was set 0.1 time the internal resistance, in spite that the safety valve operated after short circuit, occurrence of cracks in portions other than the safety valve were confirmed.

[0063]

In the external short circuit test, like this, behavior of a battery varies depending on external circuit resistance, thus for

the purpose of conducting combined use of a tab as a current fuse, it is preferable to design a value of current cutoff of a current fuse, especially assuming the external circuit resistance being not more than 0.1 time the internal resistance, taking this test results into consideration. For example, with a battery being under the fully charged state, in the case where the voltage is 4 V, the current capacity is 25 Ah, and the internal resistance is 5 mΩ, a short circuit current of approximately 800 A is to flow, therefore, from the results of the formerly mentioned tab's fusing test, it will do that as for Al tabs the total cross-sectional area may be made not more than 0.064 cm^2 being 8 times that in the case of current value of 100 A, and similarly, as for Cu tabs not more than 0.040 cm^2, and as for Ni tabs not more than 0.032 cm^2 so that the tabs fuse at the 800 A current.

[0064]

Accordingly, next, a battery whose Al tabs have total cross-sectional area of 0.06 cm^2 and Cu tabs have total area of 0.035 cm^2 and a battery whose Al tabs have total cross-sectional area of 0.1 cm^2 and Cu tabs have total area of 0.05 cm^2 were respectively produced, and an external short circuit test was conducted, setting the external short circuit resistance to 0.1 time the internal resistance. As a result, for the one comprising Al tabs with total cross-sectional area of 0.06 cm^2, immediately after short circuit, Al tabs and Cu tabs fused and both the current and the voltage indicated 0, but the other one comprising Al tabs with

total cross-sectional area of 0.1 cm^2, it was confirmed that the safety valve operated after short circuit and cracks had occurred at portions other than the safety valve.

[0065]

Next, by way of a method similar to the above described method of producing a battery, with changing area, width, etc. of electrodes, various batteries being different in battery capacity and internal resistance were formed, utilizing Al tabs, Cu tabs and Ni tabs, and an external short circuit test was conducted. As a result, it became obvious that if Al tabs are provided not more than 0.36/R (cm^2), R (mΩ) being the internal resistance, they work as current fuse when the external short circuit provides 0.1 time the internal resistance, and thus fulfill the SBA guidelines. Similarly, it became obvious that Cu tabs with not more than 0.18/R (cm^2) and Ni tabs with not more than 0.14/R (cm^2) will do.

[0066]

Moreover, it is preferable that battery reaction will halt safely without the safety valve operating in the event of external short circuit with the external circuit resistance being 1 time the internal resistance. Accordingly, similar to the former external short circuit test, using a battery with current capacity being 25 Ah and internal resistance being 5 mΩ, a battery comprising Al tabs having total cross-sectional area of 0.03 cm^2 smaller than 0.18/R and a battery comprising Al tabs having total cross-sectional area of 0.05 cm^2 larger than 0.18/R were produced

to conduct an external short circuit test. As a result, in the battery comprising Al tabs having total cross-sectional area of 0.03 cm^2, the safety valve did not operate, after short circuit, similar to the case of normal discharge, but in the battery comprising Al tabs having total cross-sectional area of 0.05 cm^2, the safety valve operated after short circuit. Nevertheless, even in this case, burst or ignition of the battery did not take place in portions other than the safety valve.

[0067]

As a result of the above, it has been understood that with Al tabs having total cross-sectional area of not more than 0.18/R cm^2, the safety valve does not operate in the event of external short circuit with external circuit resistance such as one time the internal resistance, either, and such a tab is preferable. Likewise, it has become obvious that total cross-sectional area of not more than 0.09/R cm^2 for Cu tabs, and of not more than 0.07/R cm^2 for Ni tabs will do.

[0068]

[Effect of the Invention]

As described above, according to a lithium secondary battery of the present invention, an excellent effect that without tab's fusing within a working current range since total cross-sectional area of tabs is set within an appropriate range, reduction in output loss as well as improvement in energy density may further be planned is yielded, and on the other hand, an

excellent effect that security of safety as well as improvement in safety may be planned is attained by incorporating tabs as current fuse into a battery. In addition, a remarkable effect that a battery superior in reliability is provided by having these characteristics simultaneously in combined fashion can be achieved.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a perspective view showing the structure of a wound-type internal electrode body.

[Fig. 2] Fig. 2 is a plan view showing the spread state of each positive electrode and negative electrode in wound-type internal electrode body.

[Fig. 3] Fig. 3 is a perspective view showing one embodiment of the structure of a lamination-type internal electrode body.

[Fig. 4] Fig. 4 is a cross-sectional view showing one embodiment according to the lithium secondary battery using a wound-type internal electrode body.

[Fig. 5] Figs. 5(a) and 5(b) are enlarged sectional views of the attachment part of tabs into electrodes plate.

[Fig. 6] Fig. 6 is a plan view showing one embodiment of a shape of a tab preferably usable in a lithium secondary battery of the present invention.

[Fig. 7] Fig. 7 is an explanatory drawing showing a method of pressure attachment of tabs to a rivet.

[Fig. 8] Fig. 8 is an explanatory drawing showing a method

of tightening a screw for tabs.

[Fig. 9] Fig. 9 is an explanatory drawing showing a method of measuring deviation of resistance of tabs.

[Reference Numerals]

1 ... internal electrode body, 2 ... positive electrode, 3 ... negative electrode, 4 ... separator, 5 ... tab, 6 ... tab, 7 ... internal electrode body, 8 ... positive electrode, 9 ... negative electrode, 10 ... separator, 11 ... battery case, 12 ... positive terminal plate, 13 ... rivet, 14 ... negative terminal plate, 15 ... metal foil, 16 ... electrode active material layer, 17 ... insulating sheet, 18 ... external terminal, 19 ... V-shape groove, 20 ... sealing member, 21 ... narrow parts, 24 ... bolt , 25 ... nut.

[NAME OF DOCUMENT] Abstract

[ABSTRACT]

[Theme]

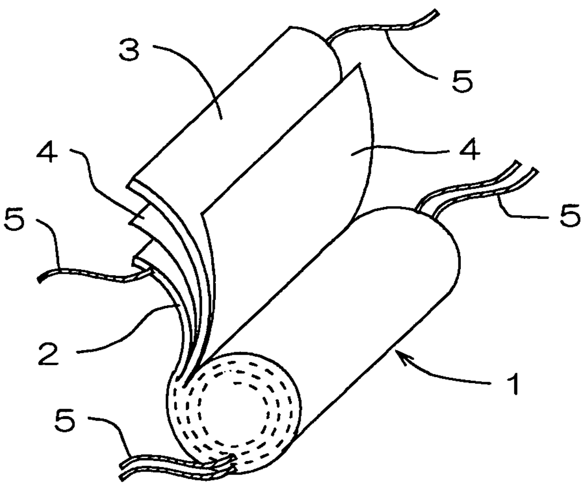
There is provided a lithium secondary battery which maintains a good charge-discharge cycle and in which safety may be secured with electricity being cut off when an excess current has occurred due to external short circuit, etc. so that the battery may not be exploded not be ignited, and in particular, to a lithium secondary battery which may be preferably used for driving a motor of an electric vehicle, etc.

[Means]

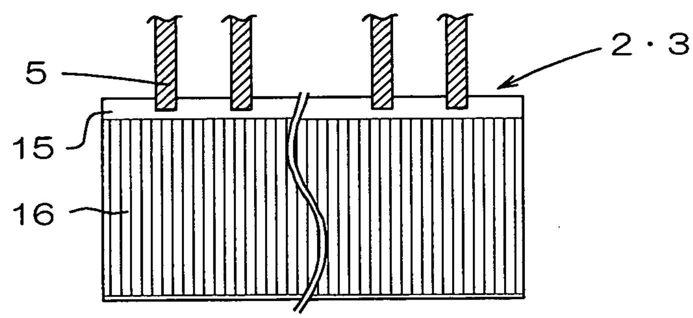
A lithium secondary battery includes: an internal electrode body 1 including a positive electrode 2 and a negative electrode 3 being wound or laminated via a separator 4 so that the positive electrode and the negative electrode are not brought into direct contact with each other, and an organic electrolyte. At least a plurality of tabs 5 to be connected to each of the positive and negative electrodes 2, 3 for current collecting have a total cross-sectional area of the tabs 5 be not less than a constant area in accordance with the quality of the material to be used for the tabs 5 so that each of the tabs for current collecting may not fuse when at least 100A current flows through the lithium secondary battery.

[Adopted Figure] Fig. 4

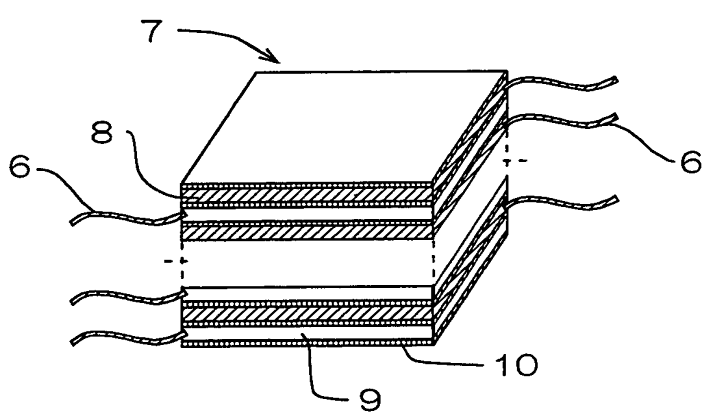
F I G. 1



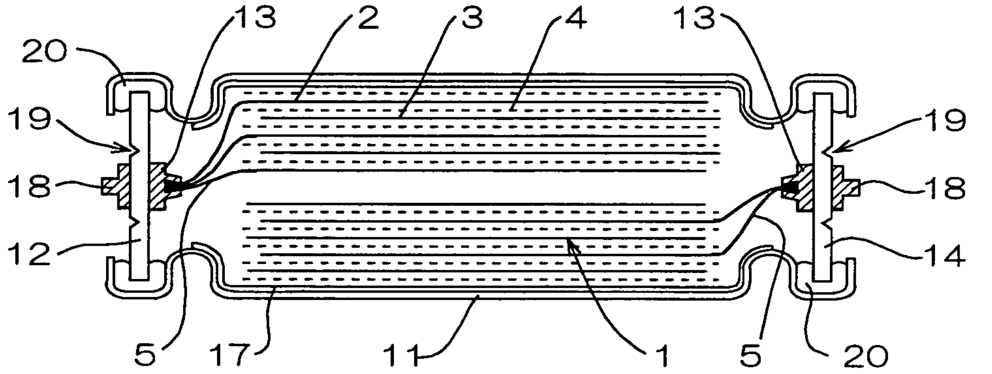
F I G. 2

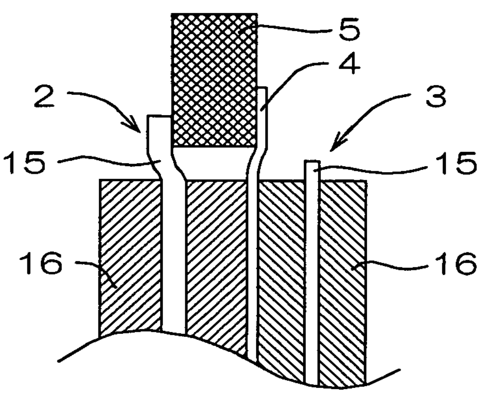


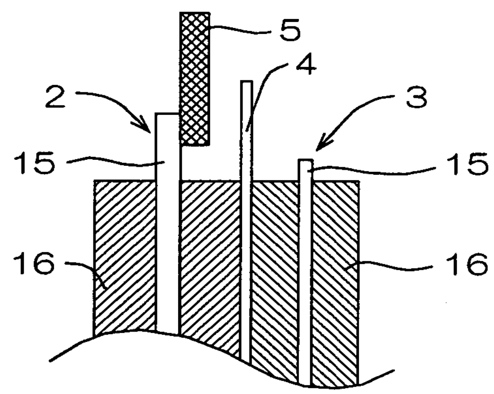
F I G. 3



F I G. 4

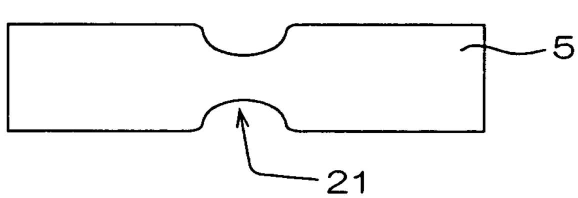




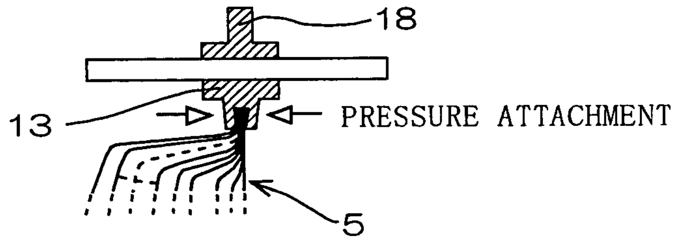


F I G. 5 (a)   F I G. 5 (b)

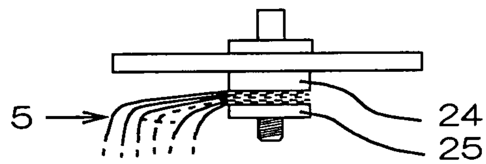
F I G. 6



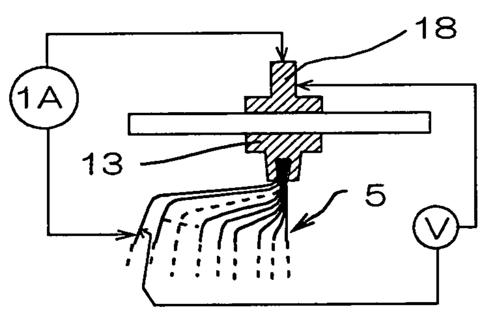
F I G. 7



F I G. 8



F I G. 9



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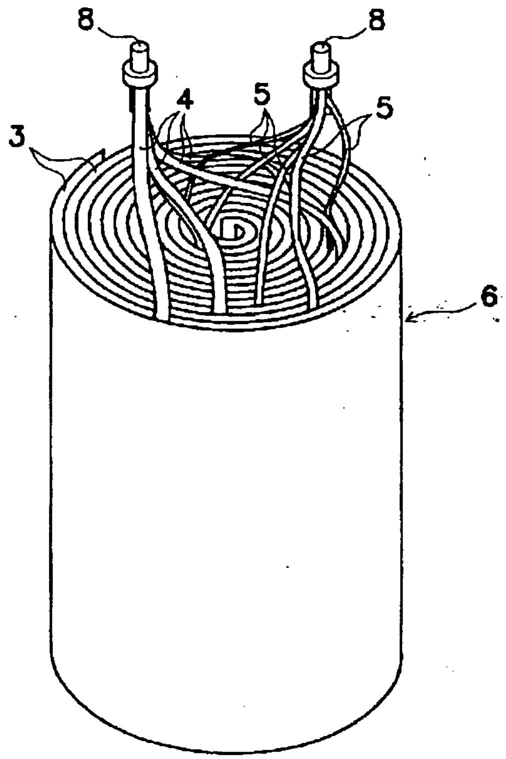
(57) [Abstract]

[Problem] To provide a battery capable of preventing internal short circuits due to fusion of both the positive electrode lead 4 and negative electrode lead 5 by causing only the

negative electrode lead 5 to fuse and preventing the positive electrode lead 4 from fusing when an external short circuit occurs.

[Means of Solution] Negative electrode lead 5 is composed of a narrow copper foil necessarily fused by an external short circuit current and positive electrode lead 4 is composed of a wide aluminum foil that is not fused by an external short circuit current.



[Claim(s)]

[Claim 1] A battery in which a positive and a negative electrode are positioned in proximity with a separator between them, with said positive and negative electrodes being connected to positive and negative terminals through one or more leads, characterized in that, based on either the material or total cross-sectional area of a lead connected to either said

positive or said negative electrode, the fusion threshold current thereof is set to a value lower than the external short-circuit current, and based on the material and total cross-sectional area of a lead connected to the other electrode, the fusion threshold current thereof is set to a value higher than the external short-circuit current thereof.

[Claim 2] A battery in which a positive and a negative electrode are positioned in proximity with a separator between them, with said positive and negative electrodes being connected to positive and negative terminals through one or more leads, characterized in that, based on the material and total cross-sectional area of a lead connected to either said positive or said negative electrode, the allowable current thereof is set to not greater than half the allowable current based on the material and total cross-sectional area of a lead connected to the other electrode.

[Claim 3] A battery in which a positive and a negative electrode are positioned in proximity with a separator between them, with said positive and negative electrodes being connected to positive and negative terminals through one or more leads, characterized in that a gap is provided around a lead connected to at least said positive or said negative electrode and covered with an insulating material.

[Description of the Invention]

[0001]

[Technological Field of Invention] The present invention relates to a battery in which positive and negative electrodes are wound or laminated with a separator between them, and the positive and negative electrodes are connected to positive and negative terminals through leads.

[0002]

[Prior Art] As shown in Figure 3, in a wound lithium ion secondary battery, a strip-like positive electrode 1 and negative electrode 2 are stacked on two separators 3, 3 and wound. Positive electrode 1 comprises a positive electrode active material 1b applied to front and back surfaces of the aluminum foil 1a and negative electrode 2 comprises a negative electrode active material 2b applied to the front and back surfaces of a copper foil 2a. Multiple positive electrode leads 4 bottom end to be connected locked by appropriate site of the positive electrode 1 top edge part, multiple negative electrode leads 5 bottom end being connected and being locked by the appropriate site of negative electrode 2. Positive electrode lead 4 consists of foil of long and narrow aluminum vertically, negative electrode lead 5 consists of foil of long and narrow copper vertically. Separators 3,3 use insulating non-woven fabric or the like where strip of wide is a little thin in comparison with these positive and negative electrodes 1,2.

[0003] The abovementioned positive and negative electrodes 1, 2 and two separators 3, 3 are alternately stacked and wound to form a battery element 6 such as that shown in Figure 4. In this case, from the upper edge of this battery element 6 protrude it does the multiple positive and negative electrode lead 4,5, in random. Then, as shown in Figure 5, in positive electrode

lead 4, the upper ends are collected, connected, and secured to a positive electrode terminal 7 which is installed in a battery case, not shown. Further, the upper ends of multiple negative electrode leads 5 are also collected and are connected and secured to negative electrode terminal 8. However, since positive electrode lead 4 and negative electrode leads 5 protrude from random positions, when connecting to positive and negative electrode terminals 7,8, there is sometimes mutual contact. Because of this, polypropylene or some other insulating tape is applied in advance to both sides of positive and negative electrode leads 4, 5 to prevent short circuiting due to contact.

[0004]

[Problems to be Solved by the Invention] In the abovementioned lithium ion secondary battery, when positive and negative electrode terminals 7, 8 are externally short-circuited, a large external short-circuit current flows through positive and negative electrode lead 4,5 inside the battery. It had not become kind of design which however, until recently, the positive and negative electrode leads 4, 5 can withstand this external short circuit current. Therefore, when external short circuit occurs and external short circuit current flows to positive and negative electrode leads 4,5, the foil of aluminum and copper melting with heat emission, fusing by being cut off, because also insulating tape dissolves and scatters in this case, cut portion becomes bare. Furthermore, only any one of positive and negative electrode lead 4,5 fuses with no limit, when both fuse together, because it is, these positive electrode lead 4 and cut portion, which negative

electrode lead 5 exposes contacting mutually, there is a possibility of causing internal short circuit.

[0005] Because of this, in conventional lithium ion secondary batteries, there is a problem in that when external short circuiting occurs, there are times when both positive and negative electrode leads 4,5 fuse inside the battery, creating the possibility of internal short circuiting.

[0006] This problem is not limited to the above-described wound lithium ion secondary batteries, but is common to all batteries of a configuration in which positive and negative electrode leads 4, 5 randomly protrude from one end of battery element 6, including elliptic batteries in which battery element 6 is elliptically wound.

[0007] However, in the process of winding positive and negative electrodes 1,2 and separators 3,3, when positive electrode lead 4 and negative electrode lead 5 are separated to the left and right respectively at the upper end of battery element 6, or when positive electrode lead 4 and negative electrode lead 5 are separated at the top and bottom ends, respectively, of battery element 6 and protrude, positive and negative electrode leads 4, 5 do not come into direct contact even when they both fuse. In addition, even in the case of laminated type battery, which through the separator 3,3, laminates positive and negative electrodes 1,2, because protruding position of positive electrode lead 4 and the negative electrode lead 5 can be separated easily, these can prevent direct contact that it does simply. But, being this kind of battery, when

positive and negative electrode lead 4,5 do fuse, because there is a possibility that contacts battery case or the like of electro-conductivity with site where the cut portion exposed by them differs respectively, through this battery case or the like, there is a problem in the form of the possibility of internal short circuiting.

[0008] Further, in the above-described conventional battery, there are times when neither positive electrode lead 4 or negative electrode lead 5 fuses during external short circuiting; in such cases, the external short circuit current continues to flow. When only the external short circuit occurs, external short circuit current being divided into several parts at a time, respectively, by positive and negative electrode lead 4,5, it flows, but when furthermore internal short circuit occurs, because it flows to positive and negative electrode lead 4,5 to which one by one internal short circuit current is actually intensively contacted, heat emission increases and the risk of the safety valve operating or the battery rupturing increase. Therefore, in order to prevent occurrence of this kind of internal short circuit, better solutions to the abovementioned problems than in the past have been strongly desired. But, even when only external short circuiting occurs, since a large external short circuit current flows into the interior of the battery, the risk of safety valve operation or batter rupture due to the ensuing heat emission cannot be entirely avoided, and there has been a need to also block external short circuit current. In order to block this kind of external short circuit current, it suffices to provide a current circuit blocking

device called a CID, but when a CID is separately installed in the battery, problems occur in that battery space is reduced and manufacturing costs are increased.

[0009] The present invention, devised in light of these problems, has for its object to provide a battery which can prevent the occurrence of internal short circuiting with the rapid fusion of just one lead and prevent the occurrence of internal short circuiting due to fusion of both leads when external short circuiting occurs.

[0010]

[Means of Solving the Problems] To solve the above-stated problems, the present invention comprises a battery in which a positive and a negative electrode are positioned in proximity with a separator between them, with said positive and negative electrodes being connected to positive and negative terminals through one or more leads, characterized in that, based on either the material or total cross-sectional area of a lead connected to either said positive or said negative electrode, the fusion threshold current thereof is set to a value lower than the external short-circuit current, and based on the material and total cross-sectional area of a lead connected to the other electrode, the fusion threshold current thereof is set to a value higher than the external short-circuit current thereof.

[0011] Based on this means, when there is a short circuit between positive and negative terminals on the exterior of the battery and an external short-circuit current flows to the leads connected to the positive and negative electrodes, since a current exceeding the fusion threshold

current flows through the lead connected to one of the electrodes, total fusion between electrodes and terminals is blocked. But, because the lead is connected to the electrode of another, the external short circuit current flowing, are not measured when it exceeds fuse threshold current of this lead, none are measured when the fuse does. Therefore, when external short circuit occurs, the lead, connected to the electrode of one side securely, fuse because the external short circuit current is blocked, it can function with these lead as fuse. Furthermore, external short circuit occurring, from the fact that there is no fuse in a lead connected to the electrode of the other, lead which is connected to positive and negative electrodes both fusing, directly or through battery case or the like, the risk of generating internal short circuit is eliminated.

[0012] Furthermore, the fusion threshold current is a current level where one or more of the leads connected to one or the other of the electrodes reaches the fusion threshold and is determined by the material and total cross-sectional area of the leads. In addition, external short circuit current is the value determined by the terminal voltage and internal resistance of battery.

[0013] In addition, the present invention comprises a battery in which a positive and a negative electrodes are positioned in proximity with a separator between them, with said positive and negative electrodes being connected to positive and negative terminals through one or more leads, characterized in that, based on the material and total cross-sectional area of a lead connected to either said positive or said negative electrode, the allowable current thereof is set to

not greater than half the allowable current based on the material and total cross-sectional area of a lead connected to the other electrode.

[0014] Based on this means, when external short circuit currents flow to leads connected to the positive and negative electrodes due to the occurrence of an external short circuit and the allowable current of the lead connected to one of the electrodes is greatly exceeded by the external short circuit current, the lead fuses, cutting off the electrode from the terminal. But, assuming that as for allowable current of lead connected to electrode of another because there is a current 2 times or greater of the allowable lead, which is connected to electrode of one side, even in this case, as for external short circuit current, it did not exceed allowable current of lead connected to the electrode of another, exceeded allowable current about the lead, which is connected to the electrode of one side does not exceed greatly. Therefore, as for the lead connected to the electrode of the other, there is absolutely no possibility of fusing with the external short circuit current or, if the fusing occurs before this, the lead connected to the electrode of one side fuses first, because the current is blocked, the fuse of lead connected to the electrode of another can be reliably avoided. For this sake, the occurring external short circuit, assuming that lead connected to one electrode did fuse because the occurred fusing is not to the lead connected to electrode of the other, the lead connected to positive and negative electrodes fuses together, directly or through a battery case or the like mutually, the risk of generating an indirect internal short circuit is avoided.

[0015] Further, the allowable current is the maximum level of current that can safely flow through the lead and is defined on the basis of the material and total cross-sectional area of the lead.

[0016] The present invention further comprises a battery in which a positive and a negative electrode are positioned in proximity with a separator between them, with said positive and negative electrodes being connected to positive and negative terminals through one or more leads, characterized in that a gap is provided around a lead connected to at least said positive or said negative electrode and covered with an insulating material.

[0017] Based on this means, even when external short-circuit currents flow through leads connected to the positive and negative electrodes due to an external short circuit and both leads fuse, the lead connected to at least one of the electrodes melts only within the insulating material and severs the circuit. That is, because as for the insulating member that opens the gap, the periphery of this lead is covered, as for receiving some heat damage to the contacting portion of the lead, as mainly it does not receive the influence of fuse for the most part with a gap, the insulation of the portion is maintained. Therefore, both leads that fuse are done directly or through the battery case or the like, the risk of an indirect short circuit is gone; this can reliably prevent the occurrence of an internal short circuit.

[0018]

[Modes of Implementing the Invention] Modes of implementing the invention are described below with reference to the drawings.

[0019] Figures 1 and 2 show a mode of implementing the present invention; Figure 1 is a perspective view of a battery element in a wound lithium ion secondary battery and Figure 2 is an exploded perspective view of a separator and positive and negative electrodes to which positive and negative electrode leads have been connected and secured. Furthermore, the symbol is applied to the same number to constituent components possessing a function similar to the prior art example shown in Figure 3 to Figure 5.

[0020] In the present mode of implementation, a wound lithium ion secondary battery will be described. As shown in Figure 2, also lithium ion secondary battery of this embodiment, uses positive electrode 1 and the negative electrode 2 and two separators 3, 3 of same constitution as the prior art example shown in Figure 3. In addition, multiple positive electrode lead 4 and the negative electrode lead 5, which are similar to respective prior art example, are connected and secured to the top edge part of positive electrode 1 and negative electrode 2.

[0021] However, the width of the foil in negative electrode lead 5 is not greater than half that in positive electrode lead 4. Negative electrode lead 5 consists of foil of copper of about 70 μm in thickness, positive electrode lead 4 is about 100 μm in thickness, but because the electrical conductivity consists of foil of aluminum of about 70% copper, if width of foil is the same, also these allowable currents become almost the same. Therefore, the allowable current

of the actual negative electrode lead 5 becomes half or less of the allowable current of the positive electrode lead 4. In addition, because the fuse threshold current of the limit where positive and negative electrode lead 4,5 reaches to the fuse reaches big value according to respective allowable current in comparison with this, fuse threshold current of negative electrode lead 5 becomes small overall in comparison with fuse threshold current of positive electrode lead 4. And, fuse threshold current of negative electrode lead 5 is small in comparison with external short circuit current, which flows in a case where lithium ion secondary battery of this embodiment generates the external short circuit, at same time, fuse threshold current of positive electrode lead 4 is set in order to become large in comparison with this external short circuit current. Furthermore, as for fuse threshold current and allowable current of positive and negative electrode leads 4,5, it is something that individual fuse threshold current and allowable current in each positive and negative electrode lead 4,5 at a time of respective multiple total is done.

[0022] Positive and negative electrodes 1,2, to which positive and negative electrode leads 4, 5 are connected and secured, are alternately stacked with two separators 3,3 and wound to form the battery element 6 shown in Figure 1. And, from the upper edge of this battery element 6 collecting the upper end of positive electrode lead 4 that protrudes randomly, in the connection to positive electrode terminal 7, from the same upper edge collecting the upper end of negative electrode lead 5, which randomly protrudes, there is a connection to negative electrode

terminal 8. In this case, since polypropylene or other insulating tape is adhered beforehand in the same manner as in prior art to both sides of each of positive and negative electrodes lead 4, 5, contacting mutually, short circuiting does not occur. And, protruding only the upper end of these positive and negative electrode terminal 7,8 on the outside, it stores up this battery element 6 inside a battery case, not shown, and the lithium ion secondary battery is completed by being filled with electrolyte solution and sealing.

[0023] In a lithium ion secondary battery configured as set forth above, when there is an external short circuit between positive and negative electrode terminals 7, 8 and an external short circuit current flows, since a current exceeding the fusion threshold current of negative lead 5 flows, all of negative leads 5 fuse and negative electrode 2 is cut off from negative terminal 8. Therefore, when external short circuiting occurs, negative electrode lead 5 fusing securely, because the external short circuit current is blocked, it can function with these negative electrode lead 5 as the current blocking means. In addition, because positive electrode lead 4 fusion threshold current is large in comparison with the external short circuit current, it does not fuse when external short circuits occur. Therefore, negative electrode lead 5 does fuse and insulating tape doing, the dissolving scatter, because assuming, that there was a kind of thing where cut portion which is exposed contacts positive electrode lead 4 this positive electrode lead 4 is covered by insulating tape, there is no possibility of internal short circuit occurring.

[0024] Furthermore, in the present implementation mode, the external short circuit current is set between the fusion threshold current of negative electrode leads 5 and the fusion threshold current of positive electrode leads 4. However, the allowable current of negative electrode leads 5 can be set irrespectively of the external short circuit current to not greater than half of the allowable current of positive electrode lead 4. In that case, these negative electrode lead 5 fuses doing only when external short circuit current which flows due to the occurrence of external short circuit exceeds allowable current of the negative electrode lead 5 largely, it blocks with negative electrode 2 and negative electrode terminal 8. But, because the allowable current of positive electrode lead 4 because there is two times or more of the allowable current of negative electrode lead 5, assuming, that external short circuit current exceeded allowable current of this positive electrode lead 4, negative electrode lead 5 fuses first, blocks external short circuit current, fusion of positive electrode lead 4 is avoided. In that case, although blocking of external short circuit currents is not limited to when an external short circuit occurs, since positive and negative leads 4, 5 do not both fuse, internal short circuiting is reliably prevented.

[0025] In addition, in the above-described implementation mode, the fusion threshold current and allowable current were made small on the negative electrode lead 5 side; a similar effect can also be achieved by making them small on the positive electrode lead 4 side. It is possible to adjust the fuse threshold current and allowable current of positive and negative

electrode leads 4,5, not only a width of foil like this implementation mode, with the thickness of foil and material of foil or number of positive and negative electrode leads 4,5. Furthermore, in the above-described implementation mode, each positive and negative electrode lead 4,5 is formed with uniform aluminum of respective one layer ones and foil of copper, but these materials are optional, and it is possible to use something where this material and cross-sectional area are modified midway. In that case, the fusion threshold current and allowable current of positive and negative electrode leads 4, 5 are determined on basis of individual fuse threshold currents in each of positive and negative electrode leads 4, 5 and the portion where the allowable current is smallest. In addition, positive electrode lead 4 and negative electrode lead 5, are not limited to multiple leads each as in this implementation mode, but may comprise a single lead each.

[0026] Furthermore, in the above-described implementation mode, a lithium ion secondary battery is described; however, implementation is possible in any other type of secondary battery or primary battery in which positive and negative electrodes 1, 2 are connected to positive and negative electrode terminals 7, 8 through positive and negative electrode leads 4,5. In addition, it is also practical with elliptic batteries, not just wound batteries. However, distributing positive and negative electrode leads 4,5 to left and right of upper edge of the respective battery element 6, in case of batteries in which they protrude, and dividing positive and negative electrode leads 4,5 into top and bottom edges of respective battery element 6, in

cases of batteries in which they protrude, in case of those which through the separator 3,3, being a battery of laminated type which it laminates, separating the positive and negative electrode leads 4,5 respectively, protrude do or positive and negative electrodes 1,2, assuming, that both the positive and negative electrode lead 4,5 did fuse originally, these doing, the direct contact internal short circuiting does not occur. But, being this kind of battery, when positive and negative electrode leads 4,5 both fuse, because there is a possibility of contact with the battery case or the like of electro-conductivity, where the place where the exposed cut portion differs respectively, if it prevents the fusing of positive and negative electrode lead 4,5 with the present invention, it is through a battery case or the like that the indirect internal short circuit can be prevented.

[0027] Furthermore, in the above-described implementation mode, insulating tape is adhered to both surfaces of positive and negative electrode leads 4,5 in the conventional manner, but it is also possible to open a gap around either positive electrode lead 4 or negative electrode lead 5 and cover it with an insulating member. If the insulating member is the same width as the foil of positive and negative electrode lead 4,5 using those of internal diameter, which is larger than this, it can at least open the gap on front and back side surfaces of this foil. When this kind of insulating member is used as insulator, when positive and negative electrode leads 4, 5 fuse, receiving some heat damage in the internal diameter part amount where the edge of foil makes contact, because of this, the complete melting of the insulating member with gap portion

stops, the insulating of these positive and negative electrode leads 4,5 is maintained. Therefore, in this case, assuming that both positive and negative electrode leads 4,5 fuse with external short circuit current because there are no instances when at least the cut portion of any one of positive and negative electrode lead 4,5 exposes insulating being done with the insulating member, internal short circuiting can be reliably prevented. In addition, in this case, fusing of both positive and negative electrode leads 4, 5 due to internal short circuiting can be prevented, like the abovementioned implementing mode it becomes a fuse threshold current of any one of positive and negative electrode leads 4,5 and without the necessity to make the allowable current small.

[0028]

[Effects of the Invention] As has been made clear in the description set forth above, based on the battery of the present invention, when external short circuiting occurs, since one of the leads functions to sever the current, reliable blocking of external short circuit currents is possible without having to provide a separate current blocking device within the battery.

[0029] In addition, when an external short circuit occurs and a lead fuses, just one of the leads connected to the positive and negative electrodes fuses, and there is no risk of an internal short circuit due to fusing of both the leads, reliably preventing safety valve operation and battery rupture.

[0030] Furthermore, when an external short circuit occurs and a lead fuses, since a gap is provided in the periphery of at least one of the leads connected to the positive and negative electrodes and covered with an insulating member, even when this leads fuses, the severed portion is not exposed and the risk of internal short circuiting is eliminated.

[Brief Explanation of the Drawing(s)]

[Figure 1] A perspective view of a wound lithium ion secondary battery in an implementation mode of the present invention.

[Figure 2] An exploded perspective diagram of positive and negative electrodes and separators to which are connected and secured positive and negative electrode leads in an implementation mode of the present invention.

[Figure 3] An exploded perspective diagram of positive and negative electrodes and the separators to which are connected and secured positive and negative electrode leads in an example of prior art.

[Figure 4] A perspective view of a battery element configured by winding positive and negative electrodes and separators in an example of prior art.

[Figure 5] A perspective view of the battery element of a wound lithium ion secondary battery in an example of prior art.

[Key to Numerals in the Drawings]

1 positive electrode

2 negative electrode

3 separator

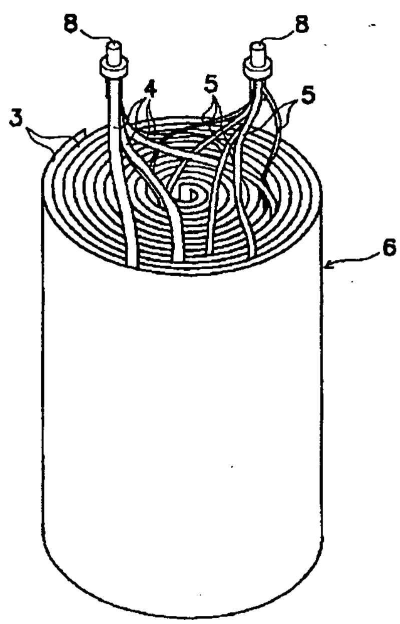
4 positive electrode lead

5 negative electrode lead

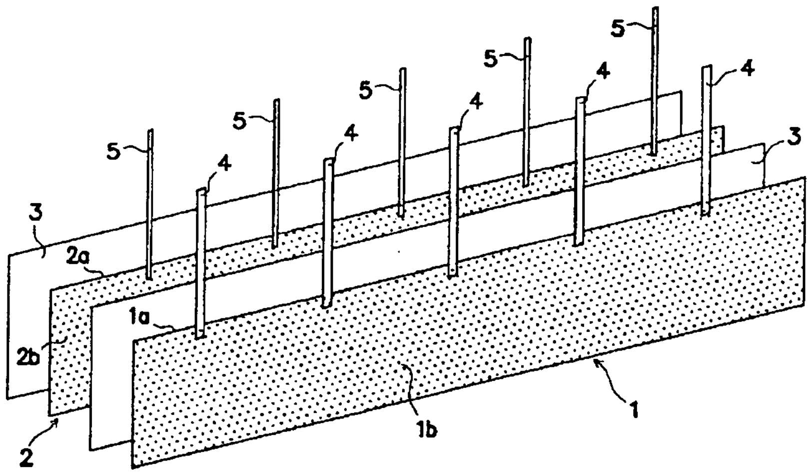
7 positive electrode terminal

8 negative electrode terminal

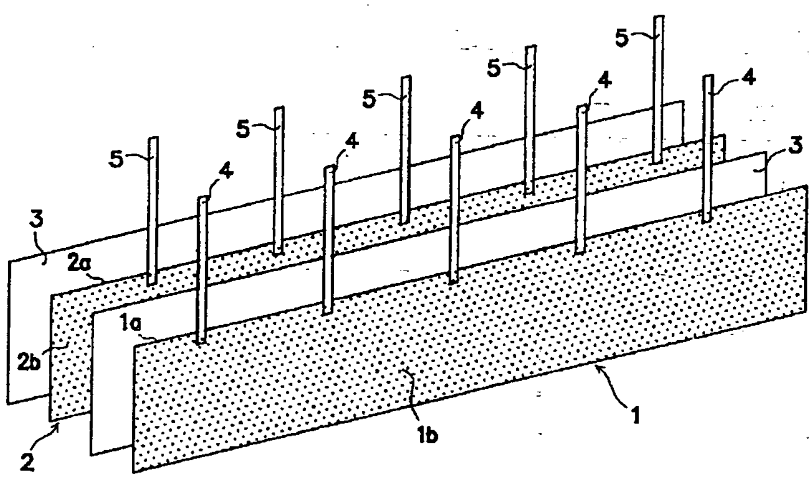
[Figure 1]



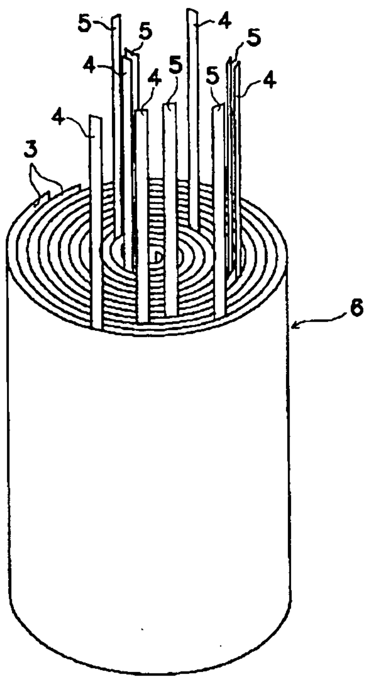
[Figure 2]

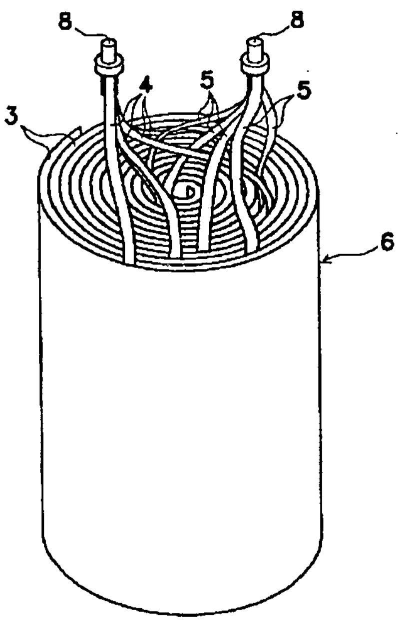


[Figure 3]



[Figure 4]





[Figure 5]